

GEOPHYSICAL VARIABLES AND BEHAVIOR: XCVIII. AMBIENT
GEOMAGNETIC ACTIVITY AND EXPERIENCES OF "MEMORIES":
INTERACTIONS WITH SEX AND IMPLICATIONS
FOR RECEPTIVE PSI EXPERIENCES¹

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Summary.—During 96 nonsequential days over a 3-yr. period, a total of 53 men and 86 women were exposed only once for 30 min. to transcranial, weak complex magnetic fields while they sat alone within a quiet chamber. They were asked to record the frequency of specific experiences after the exposure was completed. There was a significant interaction between sex and global geomagnetic activity for the incidence of experiences attributed to memories. Women reported more experiences attributed to "childhood memories" when geomagnetic activity was less than 20 nT, while men reported more of these experiences when the activity was more than 20 nT. Re-analyses of a database of "paranormal experiences" reported by 395 separate individuals over a 100-yr. period indicated that more men than women reported "precognitive experiences" on days the geomagnetic activity was above 20 nT while women reported such experiences if the geomagnetic activity was below 20 nT. These results suggest that these experiences, be they veridical or illusory, may be influenced by global geomagnetic activity that affect the neuroelectrical or neurochemical processes associated with memory consolidation or the attribution of the serial order of experiences during retrieval.

Experiences attributed to knowing the state of another person, who is dying or experiencing trauma, have been found to occur on days when the geomagnetic activity is quieter than previous or subsequent days (Persinger, 1987, 1993a). Persistent moderate and positive correlations between limbic seizures and geomagnetic activity in humans and rats suggest there is sensitivity of brain tissue to extremely weak time-varying magnetic fields within the range of tens of nanoTesla (Michon & Persinger, 1997). The sensitivity of memory to weak 100 nanoTesla to 1 microTesla complex magnetic fields designed to simulate long-term potentiation within the hippocampal formation has been shown for rats (McKay, Persinger, & Koren, 2000) and humans (Richards, Persinger, & Koren, 1993, 1996).

Although most of these "paranormal" experiences are likely to be errors of either attribution or perception, this explanation requires evidence

¹Thanks for the technical contribution over the years from Sandra Tiller, Dr. Pauline Richards, and Dr. Katherine Makarec. Publication of this manuscript was supported by Grant 71/00 from the BIAL Fellowship Programme 71/00 (Portugal). Please send correspondence and reprint requests to Dr. M. A. Persinger, Behavioral Neuroscience Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6.

from experiment rather than just belief. Persinger (1985) suggested that a subset of receptive psi experiences might involve detection of stimuli through neuroelectrical processes within the electrically sensitive hippocampal-amygdaloid complex that occur during memory consolidation. One prediction of this hypothesis (Persinger, 1993b) is that these processes would occur primarily in the right hemisphere in the normal brain given its capacity to organize or detect the organization of elements within space and their emotional significance. To enter awareness as accurate images, the neuronal representations of these right hemispheric patterns would require the appropriate intercalation with neuronal activities that generate linguistic labels and their correlated ideation within the left hemisphere.

This hypothesis would be consistent with the most common correlate of psi experiences: dream sleep (Persinger & Krippner, 1989; Krippner & Persinger, 1996). During these multiple, primarily nocturnal periods (Persinger, 1974) the focus of central processing shifts from external perceptions mediated through the thalamic-mediated classical senses to the internal perceptions of the limbic-mediated consolidation of representations (memories) of experiences acquired during the waking state (Llinas & Pare, 1991; Kavanau, 1996; Louie & Wilson, 2001). The right hemisphere becomes functionally more active than the left during paradoxical sleep (Gordon, Frooman, & Lavie, 1982) and limbic areas associated with memory and affective dimensions, specifically within the parahippocampal gyrus, display enhanced metabolic activity (Braun, Balkin, Wesensten, Gwady, Carson, Varga, Baldwin, Belenky, & Herscovitch, 1998).

The traditional literature involving receptive psi experiences, even when the issues from confounding variables in reporting bias are accommodated, indicate that women are more likely to experience these phenomena than men (Persinger, 1974). Corsi-Carrera, Herrera, and Malvido (1989) showed that normal women show greater intercorrelation of electroencephalographic activity over the left and right parietooccipital regions than do men. Women, in general, also report experiences that have been hypothesized to be reflective of more frequent intrusions of right hemispheric phenomena into left hemispheric awareness (Richards, Koren, & Persinger, 1992; Persinger, *in press*).

If these observations are consistent and generalizable, then experiences of "memories" attributed to paranormal sources should be correlated with ambient geomagnetic activity in contexts where interhemispheric interaction is enhanced by bilateral, transcerebral application of complex magnetic fields that imitate burst firing. As suggested by Gabrieli, Brewer, Desmond, and Glover (1997), hippocampal activation might be associated with experiences of recollective memories or the deliberate remembrance of a previous event. The details and attribution of the source for this "recollective experience"

that would then contribute to an episodic memory would require the activation of the context-sensitive prefrontal lobe, the anterior cingulate, and portions of the parietal lobes (Nyberg, McIntosh, Cabeza, Nilsson, Houle, Habib, & Tulving, 1996).

If these experiences involved a type of memory process coupled to hippocampal-amygdaloid activity, then women, given their greater interhemispheric intercalation (Chelley & Persinger, 1994) should report more experiences attributed to memories during periods when the geomagnetic activity was less than 20 nT compared to men. It may be relevant that the caudal splenium of the corpus callosum is statistically larger in women compared to men (de Lacoste-Utamsing & Halloway, 1982) and the dorsal hippocampal commissure (Gloor, Salanova, Olivier, & Quesney, 1993) is immediately rostral to the splenium and may have been included in the calculations of the cross-sectional area of this structure.

This model suggests that a narrow band condition exists, which we have suggested may centrally involve the dorsal hippocampal commissure, through which this information can be transferred from one hemisphere to another (Healey & Persinger, 2001) without the involvement of the usual neocortical processes coupled with "awareness." Once this information has been "transferred" through the dorsal hippocampal commissure, the reconstruction of the experience would have strong features of a "memory" but with the visual richness and emotional significance of a dream.

This may explain the frequent experiences of apparitions, "knowing" through a voice that was felt more than heard, a strong hunch, or suddenly awakening (if the person was asleep). Along with these apparent anomalous experiences, the predominant affective theme is aversive and most frequently defined as sudden anxiety or depression (Persinger, 1974). These experiences may also happen when sensing stimuli that normal senses cannot transduce (Persinger, Richards, & Koren, 1994).

Following this logic, individuals prone to this transfer of increased electrical lability would be more likely to experience and remember the process. For individuals whose brains are less intercalated, such as the average right-handed male, elevated perturbations might be required to facilitate this transfer. Correlational data have indicated that global geomagnetic activity above 20 to 30 nT and experimentally simulated geomagnetic activity within this range are associated with interference in normal hippocampal-amygdaloid function by provoking paroxysmal electrical activity (Renton & Persinger, 1998) that, if excessive, can encourage seizures (Michon & Persinger, 1997).

METHOD

Subjects and Database

In Part 1 of this study the data for 53 men and 86 women between the

ages of 19 and 30 years were selected from our files. The subjects had been enrolled in first-year psychology courses and had volunteered for relaxation studies in exchange for 2% bonus marks. All of the subjects had been tested within the same condition during the years 1989 through 1991 by different undergraduate and graduate students who were completing research for their theses. These experimenters were not aware of the hypothesis presented in the present study.

In Part 2 of this study, on the basis of the results of the experimental study, the database (Persinger, 1993a) containing the dates, sex, and type of paranormal experience was re-examined. These cases were reports of experiences that occurred between 1868 and 1967. Their specific days, months, and years had been published by various authors (see Persinger, 1993a). The three classes of paranormal experiences, which reflect various temporal discrepancies between the experience and the event, were examined.

There were a total of 395 separate experiences by different individuals that were reported to occur approximately at the time of the event (death or crisis), minutes to days before the event, or minutes to days after the event. They are traditionally labeled telepathy-clairvoyance, precognition, and post-mortem (bereavement) apparitions. Each case contained the value of the aa (average antipodal index) index (Mayaud, 1974), a measure of global geomagnetic activity per 24-hr. for the day of the experience and for each of the seven days before and after the experience. The aa index is the longest, continuous measure of global geomagnetic activity and is based upon quantitative measurements of magnetograms from single stations in the Northern (England) and Southern (Australia) hemispheres.

Procedure

In the experimental study, each subject had been exposed to procedures described in detail elsewhere (Richards, *et al.*, 1993). Essentially each was blindfolded while sitting in a comfortable chair within an acoustic chamber. Weak (1 microTesla) burst-pattern magnetic fields were applied sequentially through four sets of solenoids located in a modified motorcycle helmet that each subject wore. The positions of the solenoids were approximately over the temporoparietal regions. The burst-firing fields were presented for 1 sec. every 4 sec. for 30 min. For about half of the men and women this pattern was presented every 5 or 10 min. separated by periods of 5 min. with no field. For the other subjects these fields were presented continuously.

When the exposures were finished the subject completed the Exit Questionnaire composed of 20 items that reflect the specific sensations and experiences commonly reported in our experiments. Each item was an ordinal ranking: 0=did not occur, 1=occurred at least once, and 2=occurred frequently. All subjects were tested between 13 hr. and 22 hr. local time. No

more than two subjects had been tested on any given day. For the present study only the scores for the item "I experienced memories for childhood" were used. The relative measure for experiences of memories, to control for individual differences in the propensity to report or to score experiences, was calculated by dividing the individual score for the item by the mean for all 20 items.

The aa values for the day of and for each of the two days before and after the experiment for each subject were obtained from published sources (Geomagnetic Indices Bulletin, 325 Broadway, Boulder, Colorado 80303). The intensities were recoded into four intervals 0–20 nT, 21–40 nT, 41–60 nT, and >60 nT for each of those days. The 3-hr. kp (planetary k) indices were grouped in values of 0–1, 2, 3, 4, and >5. These integers are quasi-log transformations of the intensity of the most disturbed component of magnetograms per 3-hr. increment.

Two-way analyses of variance for the raw scores for experience of childhood memories, the relative score for this item, and the mean for all experiences were completed as a function of the increments of daily geomagnetic activity (two days before, day of, and two days after). Additional two-way analyses of variance were completed for the increments of kp values, after adjustment of the discrepancy between local and universal time, during the closest 3-hr. increment to the time of each subject's exposure. Analyses of variance and covariance with values of geomagnetic activity from adjacent days (the day before and the day after) and from adjacent 3-hr. intervals were also completed.

In the second part of the study involving the cases from the database involving spontaneous receptive psi experiences concerning death or crisis to significant others, the geomagnetic activity during the day of the experience was recoded into less than 21 nT or greater than 20 nT. Chi-squared analyses between the proportions of cases reported by men or women during periods below or above the 20 nT criteria were completed for the different types of paranormal experiences. All analyses involved SPSS software on a Vax 4000 computer.

RESULTS

The *F* ratios for the statistically significant interactions between sex and the increments of intensity of the geomagnetic activity during the day of the experiments for the experience of memories are shown in Table 1. Covariance for the geomagnetic activity during the previous day and subsequent day (simultaneously) did not change the statistical significance. The omega-squared estimates for these values indicated that approximately 7% and 9% of the variance was explained. The interaction between sex and the incre-

TABLE 1
INTERACTION OF SEX BY INCREMENT OF GEOMAGNETIC ACTIVITY FOR DAILY AND 3-HR. INDICES
FOR MEASURES OF REPORTS OF CHILDHOOD MEMORIES AND TOTAL EXPERIENCES

Variable	F	F*
Daily aa values for day of experience		
Rated intensity of memories	3.26†	3.17†
Numbers of relative memories	5.02‡	4.55‡
Average of all experiences	1.24	1.23
Three-hour K values at hour of experience		
Rated intensity of memories	3.20†	3.47‡
Numbers of relative memories	2.29	2.31
Average of all experiences	1.53	1.43

*After covarying previous interval. † $p < .01$. ‡ $p < .001$.

ment of geomagnetic activity was not statistically significant for the mean numbers of experiences. The main effects for sex and increment of geomagnetic activity were also not significant statistically for any of these measures.

The source of the interaction, as indicated by *post hoc* examination (Tukey, $p < .05$) and reflected in Fig. 1, was due to the greater incidence of experiences attributed to memories by the women when the ambient geomagnetic activity decreased compared to the greater incidence of experiences attributed to memories by the men when the geomagnetic activity increased. Polynomial analyses indicated the linear trend was significant for both the men ($F_{1,51} = 8.09$, $p < .001$) and the women ($F_{1,84} = 7.13$, $p < .001$).

As shown in Table 1, the interaction between sex and increment of kp values was significant only for the raw scores for the incidence of experiences attributed to memories. Covariance for the kp values for the 3-hr. period before the time of testing did not significantly ($F = 4.38$, $p < .01$) alter the strength of the effect. Covariance for the kp values for the 3-hr. intervals before and after (simultaneously) the experiments eliminated the statistical significance. The effect size (omega-squared estimates) for the statistically significant effects explained about 10% of the variance.

Chi-squared analyses for the proportion of men or women who reported paranormal experiences involving concurrent, future, or past events when the geomagnetic activity was either below 20 nT or above this value was not statistically significant but fell just short ($\chi^2 = 3.27$, $.05 < p < .10$; $\phi = .09$). The experiences for 45% of the 85 men in the sample occurred on days when the global geomagnetic exceeded 20 nT, while these experiences for 35% of the 310 women in the sample occurred on days with this magnitude of activity, i.e., 65% of the cases reported by women occurred when the geomagnetic activity was below 20 nT.

Separate analyses for each of the classes of phenomena indicated no statistically significant discrepancy between the proportions of men and women

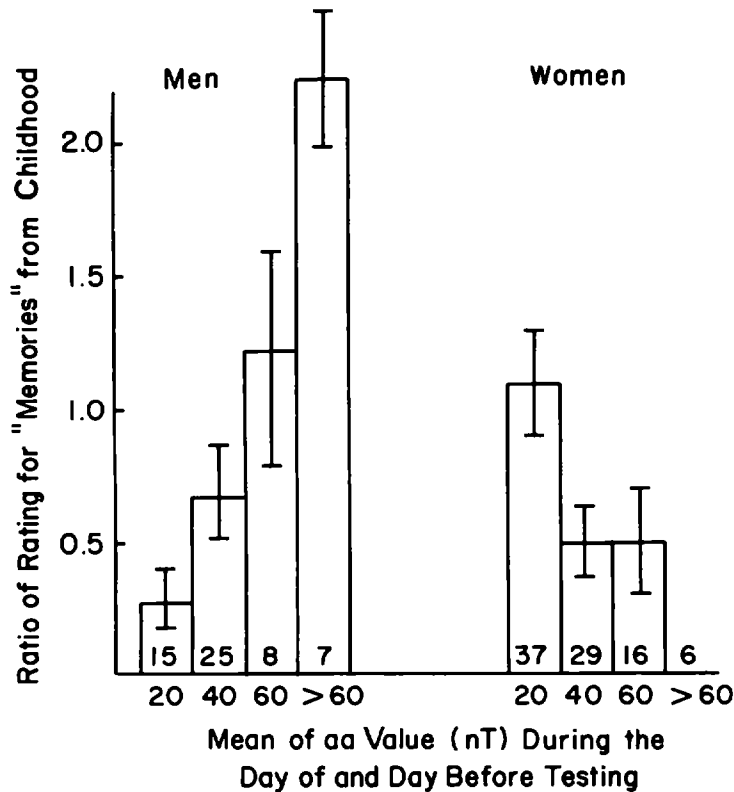


FIG. 1. Relative incidence of experiences attributed to memories during bilateral exposures to burst-firing magnetic fields and the increment of daily global geomagnetic activity (in nanoTesla) for men and women over a 3-yr. period

who reported contemporary paranormal experiences at the time of the putative stimulus ($\chi^2 = .37$, $p > .05$) or after the stimulus ($\chi^2 = .47$, $p > .05$). However, for experiences that occurred before ("precognitive") the putative events, significantly ($\chi^2 = 3.90$, $p < .05$; $\phi = .19$) more of these experiences occurred for men (61%) when the geomagnetic activity exceeded 20 nT than for the women (37%).

DISCUSSION

The apparent distortions in temporal contiguity or spatial proximity between events of death and crises and their experiences by others have been considered the subject matter of parapsychology. Although the persistent occurrence of these experiences during dreams or related altered states may suggest they are artifacts of misperception and the consolidation of these misperceptions, there may be another explanation for some of these phe-

nomena. Roll (1966) and Persinger (1985) had suggested that the limbic system involved with memory consolidation, especially during the dream state, might serve as a sensor to the stimuli that produce these experiences.

The hypothesis of vectorial hemisphericity predicts the algorithms by which the left and the right hemisphere function are slightly different and that these algorithms reflect the significant differences in micro- and macro-morphological organization (van Essen & Drury, 1997). For right hemispheric processes, whose patterns are not congruent with those that generate left hemispheric consciousness, to enter awareness intercalation between the two hemispheres must occur. The accuracy of this transformation from dimensions of meaning and spatial organization mediated by right hemispheric processes and the details of the imagery mediated by left hemispheric processes would reflect a stimulus generalization curve. Its width would be strongly influenced by the proximity between the affective nodes for these visual images and the information that is then processed by the left hemisphere.

This experimenter reasoned that bilateral application of a complex magnetic field whose temporal structure simulates burst-firing neurons within the limbic system might have increased the probability of this intercalation (Persinger, *in press*). The purpose of the study was not to discern whether there were more memories associated with these experimental fields compared to sham conditions. We have shown that memory experiences are more frequent during exposures to these fields than during sham-field conditions. Instead, the purpose was to discern if the incidence of these "memory" experiences induced by magnetic fields whose temporal structure was designed rationally and then generated experimentally within the laboratory to encourage "states of consciousness" might be modulated by changes within specific increments of intensity originating from a natural force (global geomagnetism) within which we are all immersed.

Experiences of phenomena attributed to memories have been evoked by the surgical stimulation of the hippocampal-amygdaloid formation, or its cortical inputs, by currents sufficient to produce paroxysmal discharges in epileptic patients. These currents were on the order of milliamps (Weingarten, Cherlow, & Holmgren, 1977; Halgren, Squires, Wilson, Rohrbaugh, Babb, & Crandall, 1980; Gloor, Olivier, Quesney, Andermann, & Horowitz, 1982). Application through the brain of steady-state, spatially homogeneous magnetic fields within the mTesla range can produce facilitation or inhibition of electrical seizures in epileptics (Dobson, St. Pierre, Wieser, & Fuller, 2000). The mechanism has been attributed to some variant of current induction.

However, weak (1 microTesla) complex magnetic fields whose structures imitate patterns that enhance long-term potentiation in the hippocampus, have been shown to affect the consolidation of memory in rats (McKay,

et al., 2000) and human beings (Richards, *et al.*, 1996; Healey & Persinger, 2001). If we assume rise times of 1 msec., peak strengths of 1 microTesla, and conductances of 50 ohms through the extracellular matrix, then the electric currents induced within 10 cm of tissue would occur within the range of nanoamps, or, with brief focalization, microamps. Although a mechanism by which current induction might be altered under very favourable conditions could be argued with these parameters, other physical mechanisms are more likely to be involved.

This experimenter suggests that the application of transcerebral and circumcerebral complex magnetic fields whose temporal and morphological structure approach those generated by the brain volume, as inferred by electroencephalographic spectra, interacts with the magnetic patterns of the whole brain. The interaction would involve flux line-to-flux line interaction, much like the interaction between the solar magnetic field carried by the solar wind and the geomagnetic field (Lyon, 2000). If this analogy is valid the interaction between the two tensors produced by the spatially and temporally changing fields within the brain volume and the volume of the applied fields would generate interference patterns and perturbations whose structure would be the information incorporated into consciousness.

Jacobson and Yamanashi (1994) have derived an equation, based upon the relationship between energy and matter, whose solutions predict the effectiveness of intensities within the picoTesla range. The efficacy of these intensities, particularly when complex patterns are applied over the right hemisphere, have been reported during several experiments by Sandyk (1995). Jacobson's solutions indicate that specific intensities of magnetic fields and terrestrial rotational and orbital speeds affect macromolecules with specific masses.

The range in geomagnetic activity is in the order of tens of nanoTesla, about 1,000 times stronger than the values predicted and shown to be effective by Jacobson and Sandyk, although the major temporal variations are in the range of mHz rather than Hz. The results of the present study indicated that the geomagnetic activity during the period associated with the bilateral application of the complex magnetic field affected the numbers of experiences reported as memories. For women these experiences were more common when the geomagnetic activity was below 20 nT, and for men these experiences were more common when the activity was above 20 nT. This interaction between ambient geomagnetic activity and sex of subject was persistent even when the shared variance with the activity from the day before and after was removed.

This interaction would be consistent with the mild but significantly greater interhemispheric coherence in electroencephalographic activity over the parietal and occipital lobes for normal women as well as the classical

"less lateralization" of the normal, right-handed woman's cerebrum. Periods of increased global geomagnetic activity over about 20 to 30 nT are known to suppress melatonin levels (Bartsch, Bartsch, Mecke, & Lippert, 1994), increase the probability of limbic seizures in epileptic rats (Michon & Persinger, 1997), and to affect the homing of pigeons (Semm, 1988). If we assume that increased electrical lability and paroxysmal "noise" within the normal woman's limbic system and its thalamic connections to the cerebral cortices occur above this threshold, then interhemispheric coherence should decrease. In the present study this was associated with relatively fewer memory experiences.

On the other hand, the experiences of memories for men increased when the geomagnetic activity exceeded 20 nT. This observation suggests that this enhanced geomagnetic activity either decreased transiently the functional lateralization between the two cerebral hemispheres or generated comparable interhemispheric variation that facilitated the intercalation.

There is empirical evidence for this relationship between functional hemispheric dominance and geomagnetic activity. For example, Belisheva, Popov, Petukhova, Pavlova, Osipov, Tkachenko, and Baranova (1995) found that during low geomagnetic activity right-eye dominance was replaced by left-eye dominance that was accompanied by an "unstable" functional state of the brain. If one assumes that this shift to left-eye dominance is also associated with a mild increase in right hemispheric dominance, then periods of low geomagnetic activity would enhance right hemispheric function. This might increase the interhemispheric coherence for the normal female brain. Conversely, during periods of increased geomagnetic activity shifts from right to left hemispheric dominance could be associated with a brief period of interhemispheric coherence during which time the male becomes aware of this information. Sex differences in response to geomagnetic activity could help explain the conspicuous dominance in the proportion of women who report psi experiences (Persinger, 1974). This preponderance may not simply be an artifact of social expectations or cultural roles.

Reanalysis of the database for spontaneous cases of receptive psi experiences indicated that there were proportionally more women than men who experienced feelings of death or crisis for significant others when the geomagnetic activity was below 20 nT. There were proportionally more men than women when the geomagnetic activity was above this value. These results are congruent with the first part of the study and indicate that, for men to experience (or report) these phenomena, the ambient geomagnetic activity must be higher than for women. This pattern would be also congruent with the greater sensitivity of the normal female brain to either the intensity of geomagnetic changes or the translation of these changes from

right hemispheric representations into left hemispheric awareness (Richards, *et al.*, 1992).

Obviously, the validity of the experiences in neither the experimental nor epidemiological component of this study was measured. At present they should be considered reports of experiences whose veridicality may or may not be correlated with the experiencers' attributions and labels. Even if these experiences ultimately demonstrate that psi experiences are misperceptions or "mismemories," the correlation between their frequency and incidence of occurrence suggest a sensitivity of human cognition to an environmental force that has been largely ignored.

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